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CHAPTER 18

Livestock at the heart of 'climate-smart' landscapes in West Africa

Jonathan Vayssières, Mohamed Habibou Assouma, Philippe Lecomte, Pierre Hiernaux, Jérémy Bourgoin, Frédérique Jankowski, Christian Corniaux, Mathieu Vigne, Emmanuel Torquebiau and Alexandre Ickowicz

In a context of strong human demographic growth, climate change is a challenge for West African agriculture, which is primarily rainfed and which remains highly dependant on local natural resources. It is therefore imperative to design a 'climate-smart'[1] agriculture, one that is sufficiently productive in food, adapted to climatic variations and which releases limited amounts of greenhouse gases.

The scientific literature indicates that options for mitigating or adapting to climate change are almost always analyzed at infra levels (plot, herd) or at meso levels (farm, household) in an isolated manner, disconnected from other components of the system. This chapter uses a holistic approach to show how the concept of the 'climate-smart' landscape encourages us to reflect more on the possible synergies between the three objectives of production, mitigation and adaptation.

THE CONTEXT OF THE STUDY

We rely on the first results from research conducted in different regions of Senegal (Figure 18.1): Ferlo, the groundnut basin, and Upper Casamance. These regions have predominantly sandy soils and include a broad range of Sahelo-Sudanian agroecological contexts. The advantage of covering such a wide rainfall gradient (annual rainfall ranging from 250 to 1200 mm) is to be able to analyze the effect of variable climatic constraints on the relationships between production, mitigation and adaptation. The study in Senegal focused on two types of landscapes: the service area of a borehole (about 700 km^2) in the pastoral zone (Ferlo) and the village terroir

1. Referring to the most commonly accepted definition, which stresses food security and sustainable development, where gains of productivity, improved resilience and emission reductions are means to achieving both objectives (Lipper *et al.*, 2014).

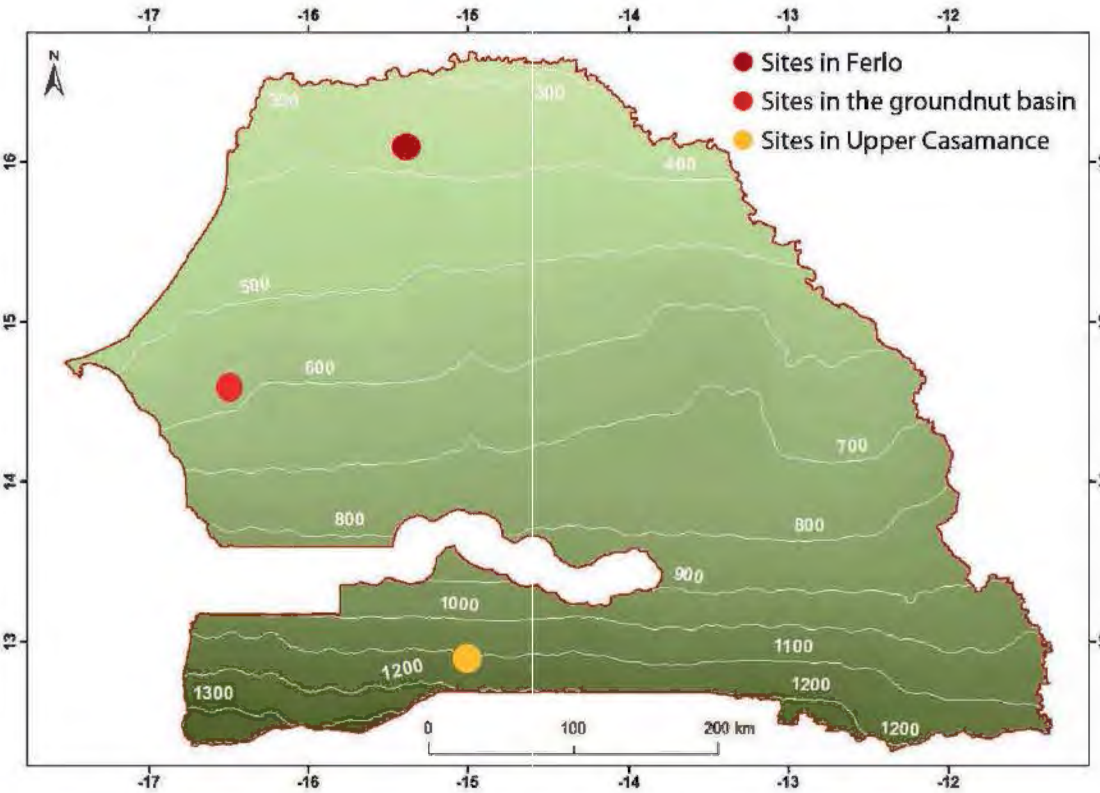

Figure 18.1. Distribution of the three study sites in Senegal across the rainfall gradient, covering a large range of climatic constraints for the analysis of their effect on the relationships between production, mitigation and adaptation.

(about 10 km^2) in the agro-pastoral zones (groundnut basin and Upper Casamance). These landscapes correspond to management units controlled by pastoral or village communities (about 360 households per borehole service area and about 120 households per village terroir).

Landscape organization, herd mobility and adaptation

In most of the landscapes studied, herd mobility is an important response to the high variability in rainfall and forage resources over time and space. Herds move on a daily basis in the borehole service area or in the village terroir (Chirat *et al.*, 2014) or, at the regional scale, over distances of several hundred kilometres (Leclerc and Sy, 2011). Local breeds have a high plasticity: they are able to adjust their daily feed intake according to the available forage types, and to store/use their accumulated body reserves – Assouma (2016) at Ferlo, Wade (2016) in the groundnut basin and Ezzano (2002) in Upper Casamance. Farmers leverage these capacities in agro-pastoral zones to maintain the herds and the required levels of organic fertilization despite high variations in forage availability. In fact, in dry seasons, animals consume plant parts that are not easily digestible (Box 18.1), leading to an increased production of faeces. Those low digestible resources are more used in drought years. Given the limited access to mineral fertilizers and, consequently, the importance of organic fertilization in maintaining soil fertility and crop yields, the role of herds in stabilizing crop production levels in agricultural landscapes is better understood.

Box 18.1. *Faidherbia albida*, a tree with multiple benefits forming the basis of a 'climate-smart' agricultural system in the Sahel.

Emmanuel Torquebiau

Faidherbia albida, or *kad* in *Sereer*, is an important leguminous tree of Sahelian agricultural landscapes, extending across the width of Africa, from Senegal to Ethiopia. Farmers find its inverted phenology very useful: it sheds its leaves in the growing season, and shades the soil with its foliage in the dry season. This characteristic helps reduce soil evaporation, while providing livestock with a shaded, cool environment during the dry season. Because of its ability to fix nitrogen from the air through root symbiosis with *Rhizobium* bacteria, the *kad* improves soil fertility. Several studies have shown that crop yields are higher in agroforestry plots that have *kad* growing in association. Finally, it is a forage tree whose foliage and, above all, pods (very high in protein and with high nutritional value) are much sought after by livestock. This exceptional versatility has made the *kad* a model agroforestry tree, frequently cited in the literature on agricultural development in dry Africa under the name of 'evergreen agriculture', mainly because of its potential for ensuring adaptation to climate change and its mitigation at the same time.

In Ferlo, due to low human population density and erratic rainfall, croplands are very limited and they do not affect herd mobility. In wetter regions, population pressure and the prominence of croplands in the landscape have a greater negative impact on herd mobility.

In the groundnut basin, past dynamics of crop extension at the expense of rangelands are increasingly hindering the presence of herds (Vayssières *et al.*, 2015): crop density is so high that less than 10% of the space is available for animal mobility (Ndiaye *et al.*, 2016). To address these constraints, some village communities have built landscapes organized around fallows (Audouin *et al.*, 2015) and networks of corridors connecting rangelands to facilitate herd movements and optimize the use of the residual space for herds (Figure 18.2).

Landscape organization, maintenance of soil fertility and food production

The borehole service area includes five types of land units: the vicinity of the borehole, natural ponds, settlements, native rangelands and forest plantations (Assouma, 2016). Similarly, the village terroir is divided into four types of land units: housing, home fields, bush fields and native rangelands.

In the pastoral zone, the daily movement of the herds within the borehole service area ensures the transfer of nutrients and carbon between land units (Assouma, 2016). Organic matter accumulates in land units where animals spend more time resting (settlements) or watering (in the vicinity of the borehole and around the ponds). Conversely, the biomass ingested by animals exceeds their excretions in grazing land units (native rangelands and forest plantations).

In the agro-pastoral zones, equivalent transfers are noted from the rangelands to the home fields (Figure 18.3), notably through the practice of night corralling (Manlay *et al.*, 2004; Saunier-Zoltobroda, 2015). This practice is meant to benefit fields close to houses that can be more easily monitored and maintained. The concentration of organic matter and labour resources on food crops contributes to household food security in a context of biomass and nutrient scarcity.

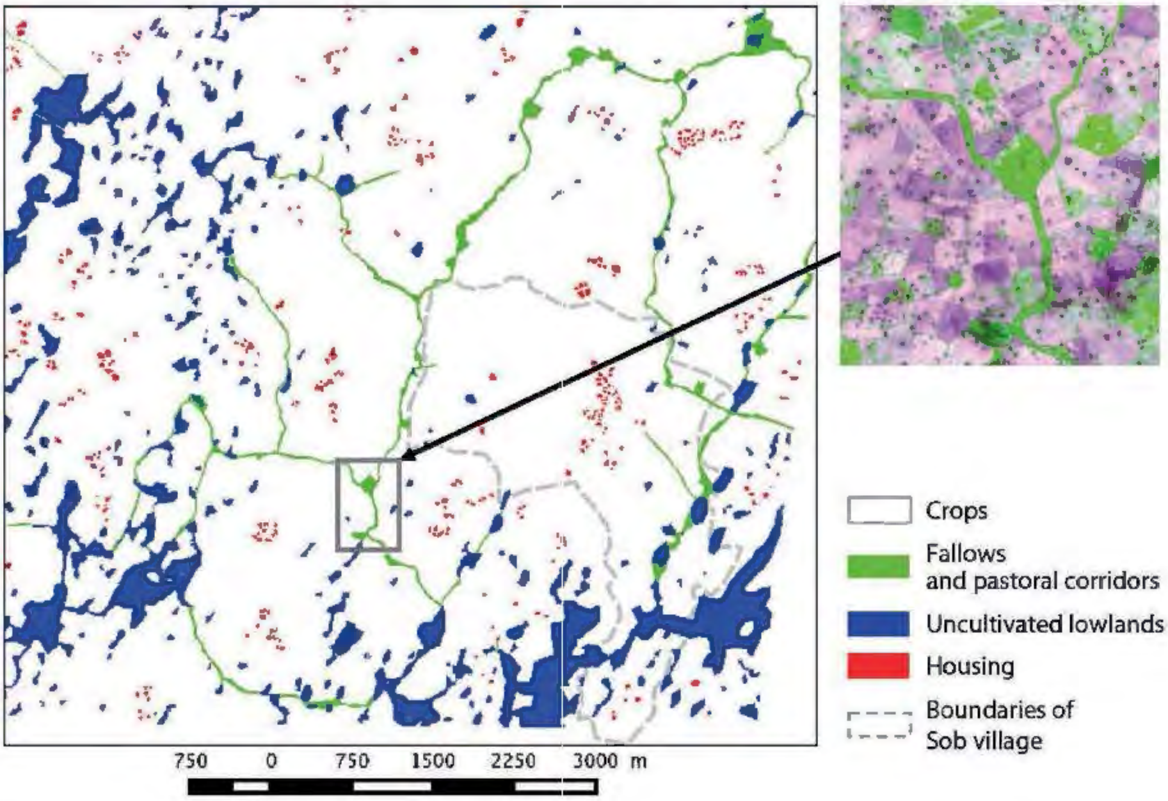

Figure 18.2. Land use map of the area in and around Sob village terroir in the groundnut basin of Senegal highlighting the existence of livestock corridors (in green) despite a landscape dominated by croplands (white) (Albrecht, pers. com.).

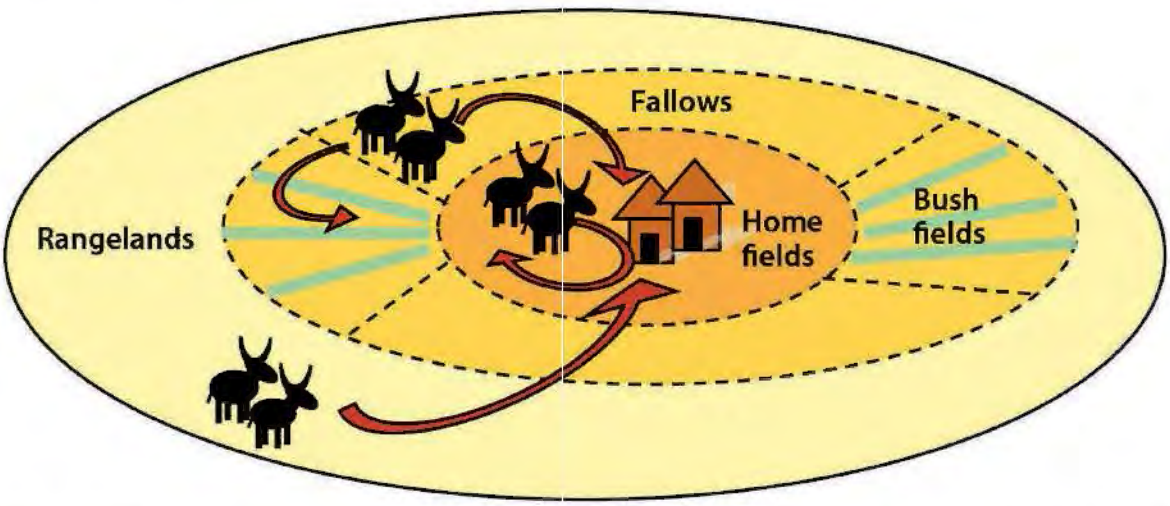

Figure 18.3. Landscape organization in concentric rings and fertility transfers by mobile herds (red arrows), accounting for 60 to 80% of the horizontal flows of nutrients and carbon within the agro-pastoral village terroir.

Landscape organization and greenhouse gas balance

An increased presence of animals and a concentration of mineral elements in some land units lead to a marked spatial heterogeneity of greenhouse gas emissions and carbon sequestration.

Land units in which animal manure gets accumulated (vicinity of the borehole, ponds and settlements for pastoral systems, housing and home fields for agro-pastoral systems) have positive greenhouse gas balances (more emissions than sequestration, in CO_2 equivalent) whereas land units from which forage biomass is removed (native rangelands and forest plantations) have negative greenhouse gas balances (Assouma, 2016).

Extensive livestock practices are at the origin of the main sources of greenhouse gas emissions in the landscape due to the consumption of low-digestible feeds (methane emissions from enteric fermentation) and the direct deposition of excreta on pastures (nitrous oxide from soil), but it prevents some emissions due to ingestion and trampling (soil incorporation) of available plant biomass, thus limiting bush fires and termite activity. The use of organic matter produced by animals to fertilize fields also curtails the use of mineral fertilizers, which are an indirect source of greenhouse gas emissions. Moreover, the presence of large livestock herds, with variable stocking rates (from 0.5 to 2 tropical livestock units per hectare depending on annual rainfall), does not inhibit carbon sequestration in the soils of pastoral or agro-pastoral landscapes. Thus, the greenhouse gas balance of the borehole service area may be slightly negative (Assouma, 2016). Greenhouse gas emissions are globally offset by carbon sequestration in trees, soil and animals. Similar results are found in agro-pastoral village terroirs when native rangelands occupy an important place (Ndao *et al.*, 2016).

Towards the design of more productive landscapes that regulate their interactions with the climate

Our work in Senegal shows that extensive livestock systems play a key role in the landscape's ability to produce food, and to adapt to and mitigate climate change. Indeed, many landscapes are built collectively to favour herd movements and crop-livestock integration. This balance between crop and livestock activities is disturbed in many parts of West Africa by the expansion of housing and croplands at the expense of rangelands (Ickowicz *et al.*, 1999; Vayssières *et al.*, 2015; Ndiaye *et al.*, 2016). This study describes landscape organizations and cropland/rangeland ratios in which the use of local resources is optimized, and in which a balance between production, adaptation and mitigation is reached. The analysis of the trade-offs between these three pillars of 'climate-smart' agriculture can be undertaken using a spatially explicit and dynamic climate modelling approach at the landscape level. It is a promising option for designing 'climate-smart' landscapes. It helps assess the role of landscape organization on the services rendered (Sané *et al.*, 2016), evaluate the effect of the past dynamics of these landscapes on the evolution of services (Grillot *et al.*, 2016) and design new 'climate-smart' landscapes with the local stakeholders, taking into account future environmental changes (Grillot *et al.*, 2015).

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